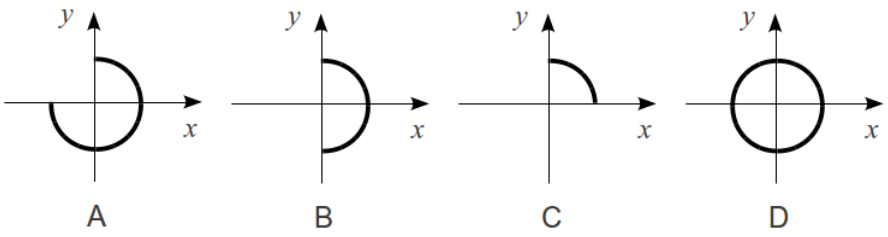
## PROBLEM SET 1

Due: 22 September 2016, 2 p.m.

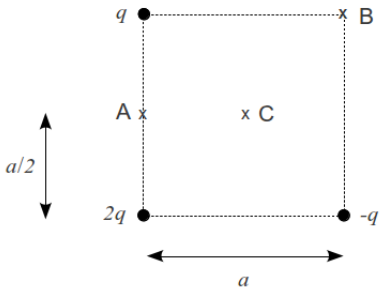
**Problem 1.** Four circular plastic rods are charged uniformly, each with charge $Q < 0$. Rank the four arrangements according to the magnitude of the electric field at the origin. Explain your answer.




*(3 marks)*

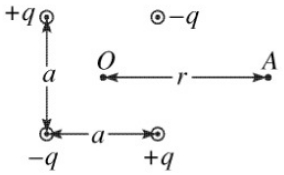
**Problem 2.** Three charges are placed in the vertices of a square. Find the electric field at points $A$, $B$, and $C$ (the center of the square). For numerical calculations assume: $q = 1$ nC, $a = 10^{-10}$ m.

*(3 × 1 marks)*




**Problem 3.** Electric quadrupole consists of two positive and two negative charges of the same absolute value $q$, arranged as in the figure below. Find the electric field of the quadrupole at distance $r \gg a$ from its center $O$, with the line $OA$ parallel to one of the sides of the square.

*(4 marks)*

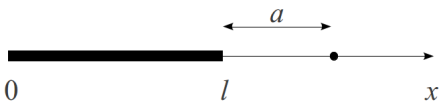


**Problem 4.** A rod of length $l$ is charged with linear density $\lambda < 0$. Find the electric field on the axis of the rod, at distance $a$ from one of the ends, if

(a) $\lambda = \text{const}$,

(b) $\lambda = Ax$, where $A$ is a constant.

*(2 + 3 marks)*




**Problem 5.** A thin disk with a circular hole in its center has its inner radius $R_1$, and the outer radius $R_2$. The disk is uniformly charged, with surface charge density $\sigma > 0$.

(a) Find the electric field on the axis of the symmetry of the disk perpendicular to its surface.
Rather than solving this problem by direct integration, use results and formulas derived in the lecture.

(b) Show that at points on this axis, sufficiently close to the geometric center of the disk, the magnitude of the electric field is approximately proportional to the distance from the center. Then consider a particle with mass $m$ and negative charge $-q$, which is placed on this axis, at distance $0.01R_1$ from the center of the disk and is free to move along the axis. Show that, after the particle is released at $t = 0$, its motion may be treated as harmonic. Find the period of oscillations.

*(2 + 3 marks)*

**Problem 6.** Two thin rods of length $l$ lie along the $x$-axis, one between $x = a/2$ and $x = a/2 + l$, and the other between $x = -a/2$ and $x = -a/2 - l$. Each rod has positive charge $Q$ distributed uniformly along its length.

(a) Show that the magnitude of the force that one rod exerts on the other is

$$F = \frac{Q^2}{4\pi\varepsilon_0 l^2} \ln\left[\frac{(a+l)^2}{a(a+2l)}\right].$$

(b) Show that if $a \gg l$, the magnitude of this force reduces to $F = Q^2/4\pi\varepsilon_0 a^2$. What is the interpretation of this result?
*Hint*. For $|u| \ll 1$, you may find the expansion $\ln(1+u) = u - u^2/2 + u^3/3 - \ldots$ helpful.

*(4 + 2 marks)*